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Differential acquisition rates for different types of information from pictures

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In three picture-recognition experiments, we investigated the characteristics of "specific feature" and "holistic" information hypothesized to be extracted from pictures. In each experiment, exposure time was varied at study. The recognition test was two-alternative forced-choice in which the target/distractor relationship was manipulated in such a way that responding on the basis of one type of information or the other was required. The results indicated that following one fixation on a picture at the time of initial study, performance based on holistic information was superior to performance based on specific feature information, whereas the reverse was true following sufficient study time for multiple fixations. These results support a view of pictorial information acquisition which postulates that most holistic information extracted from a picture is extracted during the first eye fixation on the picture, whereas subsequent fixations have the primary purpose of seeking out specific, informative features.

Introduction

When an observer is presented with a series of pictures followed by a recognition test, performance on the recognition test generally improves with increasing amounts of initial presentation time (e.g., Loftus and Bell, 1975; Potter and Levy, 1969). This finding raises the question of how we might characterize different types of information that are extracted from a picture and stored in memory following a relatively long as compared to a relatively short picture presentation.

Intuitively, it seems that there are two general ways in which people make recognition decisions about complex scenes. Sometimes the decision is made on the basis of a specific, salient feature in the picture (e.g., "Yes, I've seen it; there's that strangely-placed fire hydrant I noticed" or "No, I haven't seen it; I would have remembered the kangaroo"). Other times, a decision is made because the picture simply "looks familiar" or "looks unfamiliar".

To explore the validity of such intuitions, Loftus and his colleagues have introduced a technique designed to operationalize and investigate these two types of responses (Loftus, 1972; Loftus and Bell, 1975; Loftus and Kallman, 1979). The technique is quite straightforward: During the test phase of a yes-no picture recognition

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experiment, the subject is asked to identify each yes-no recognition response as being based on a specific feature or on the picture's general familiarity. Several results of interest have emerged from this paradigm. First, for target pictures, the number of correct responses based on specific features increases as a function of the original (study) exposure time of the picture. Second, recognition performance (d′) was substantially better when it was based on a specific detail relative to when it was based on general familiarity.

Different information underlying different responses

It seems reasonable to suppose that the two types of responses—specific detail and general familiarity—may be based on different types of information acquired from the picture at the time of original viewing.

Given this supposition, how might we characterize these different types of information? Consider first specific feature responses. Informal analysis of the sorts of features that subjects name indicates that the features tend to be unusual with respect to the rest of the picture. Thus, subjects may comment on the odd color, or the strange placement of the bicycle, or the funny angle formed by the tree branch. Several experimental findings are in accord with such observations. Loftus and Mackworth (1978) have found that eye fixations during original viewing tend to fall on objects that are defined *a priori* to be unusual. Friedman (1979) has examined recognition performance when specific details had been changed in a distractor picture relative to the original target. She found that performance decreased as a function of *a priori* rated probability that the changed object belonged in the rest of the picture.

It has also been documented that subjects are able to identify the gist or schema of a picture quite soon—probably during the first eye fixation after that picture appears (Biederman, 1972; Biederman, Rabinowitz, Stacy and Glass, 1974; Palmer, 1975; Potter, 1975, 1976). Given this finding, the role of unusual features is clarified and a coherent theory begins to emerge, which is akin to that suggested by Schank and Abelson (1975) for textual material and extended by Friedman (1979) and Goodman (1980) for pictures. The general idea is that a presented picture quickly activates a pre-formed schema (or gist or frame). Following schema identification, specific features are sought, extracted, and stored in memory. The schema guides the search for these features in the sense that the probability that a particular feature is elected for extraction and storage is a decreasing function of the *a priori* probability that the feature had already existed in the pre-formed schema. Suppose, for example, that a picture of a street scene is presented. The presence of a car in the street would be unlikely to be specifically encoded because cars turn up frequently in streets, and therefore a car would already be part of the "street-scene schema". In contrast, the presence of a circus clown would be a likely candidate for addition to the memory representation of the picture because clowns do not customarily form part of the street-scene schema. (In Schank and Abelson's formulation, the out-of-place clown would be a likely candidate for inclusion on an encoded "weird list").

Consider now the sort of information that would lead to a "general familiarity" response. Subjects are unable to verbalize about the nature of such information, and often claim that they are making a pure guess (although in fact they are not) when they use it as a basis for responding. We hypothesize that this information (termed "general visual information" by Loftus and Bell, 1975) includes overall, holistic aspects of the picture and preserves physical information such as spatial relationships. The evidence for the extraction of this kind of information stems from experiments yielding the conclusion that two types of information, often termed "verbal" and "visual", are extracted from pictures (Davies, Milne and Glennie, 1973; Petrinovich and Hardyck, 1970; Snodgrass and Antoine, 1978); that these two codes may be stored independently (Bahrick and Boucher, 1968; Mandler and Stein, 1974; Paivio and Csapo, 1973) and that they may be processed by two independent coding systems (Brooks, 1967; 1968; Seamon and Gazzaniga, 1973; Sperry, 1961; 1968).

To summarize, then, we postulate two types of information extracted from a picture: holistic and specific feature. The three experiments that we will report in this paper are designed primarily to provide opertional definitions for these two types of information and, given these operational definitions, to investigate the relative time courses by which these two types of information are extracted from pictures. An additional purpose (Experiment III) is to assess the degree to which they enter independently into a recognition memory decision. All experiments used a picture-recognition paradigm in which exposure time was varied at the time of original study, and a two-alternative, forced-choice (2AFC) procedure was used at the test. Following the logic of Jean Mandler (e.g., Mandler and Johnson, 1976), we attempted to arrange the target/distractor relationship such that a particular sort of information—in this case, either specific feature or holistic information—would be necessary for responding.

We operationalized the need to use one or the other of these types of information in the following way. To require the use of specific feature information half of the targets differed from their distractors in that a particular detail was changed. For instance, a pack of cigarettes in a target picture may change into a tape measure in the distractor. Hence, prior encoding of the detail was necessary for above-chance performance in this condition. *A priori*, it was less clear how to operationalize holistic information and we eventually decided to do it in two different ways. In Experiment I, half the targets differed from their distractors in that target and distractor consisted of the same scene photographed from a somewhat different camera angle. In Experiments II and III, half the targets differed from their distractors in that they were reversals (mirror images) of one another.

Experiment I

The primary independent variables in all three experiments were the exposure duration of target pictures at study, and target/distractor relationship at test. However, Experiment I had a secondary purpose, which was to determine what effect, if any, increasing the interstimulus interval (blank time) between picture presentations had on memory for specific feature versus holistic information. In past studies, it has been found that increasing blank time leads to superior recognition performance (Intraub, 1980; Tversky and Sherman, 1975; Weaver, 1974). Presumably, this improvement in memory resulted from increased post-picture rehearsal opportunity. By varying blank time in the present study, we hoped to identify what information was augmented following picture termination.

Method

Subjects

Seventy-two undergraduates at the University of Washington participated in Experiment I for course credit. They were run in groups of no more than four.

Stimuli and design

The study slide set consisted of 80 black and white slides of naturalistic scenes (e.g., landscapes, playgrounds, etc.). The first 24 slides and the last eight in the study sequence were filler items—subjects were not tested on these, although they were unaware of this at the time of the study. The remaining slides were randomly divided into two slide sets: sets A and B. For half of the subjects (Group 1), slides in Set A were paired with detail distractors in the 2AFC test, whereas slides in Set B were paired with angle distractors. For Group 2, slides in set A were paired with angle distractors whereas set B slides were paired with detail distractors. Additionally, each slide served equally often as a target and a distractor.

Presentation time and blank time were both between-subjects variables. Presentation times were either 250, 500 or 1,000 ms, while blank times were 2, 4 or 6 s. It was assumed that subjects would have time for only a single eye fixation at an exposure time of 250 ms; the longer presentation times, however, provided ample opportunity for multiple fixations. There were nine combinations of presentation and blank times, with eight subjects serving in each condition. Of the eight in each condition, four were assigned to Group 1, and the other four to Group 2.

Apparatus

During the study session, slides were projected onto a screen by a Kodak random access projector equipped with a Gerbrands tachistoscopic shutter. The pictures subtended a visual angle of approximately 10 degrees. The screen was dark during blank times. A second carousel projector was used in conjunction with the random access projector for projecting test slide pairs. The quality of the images projected by the two projectors was indistinguishable.

Procedure

At study, subjects were told that they would be shown 80 slides of "everyday" type scenes, and they were informed as to slide on and off times. Slides were presented in the order in which they occurred in the tray. Subjects were informed that they would have a 2AFC test on the slides, but the relationships of distractors to targets were not mentioned.

Forty-eight test trials were administered no more than ten minutes after the conclusion of the study session. The order in which the slides were tested was the same as the order of presentation during study, although, as noted earlier, the first 24 and the last eight slides presented during the study session were not tested. On each trial, the target and the appropriate distractor were projected, one immediately above the other. Half of the angle distractors and half of the detail distractors appeared in the upper position according to a random schedule. The subject's task was to indicate whether the top or the bottom slide was the one that had been presented at study. The subject also indicated the basis of his or her response. This was done to validate the experimenter's initial classification of the slide pair as probing either details or angles. Subjects indicated whether their decision was based on differences between the two slides in (1) a detail, (2) the angle, or (3) other (e.g., contrast or overall quality differences between the pictures). The subject's responses regarding the basis of their 2AFC response agreed with the experimenter's on 90% of the trials.

Results

Performance (response probability) for all eight combinations of exposure time and blank time are shown in Table I. An analysis of variance was performed on these data with presentation time, blank time, and group as between-subjects variables; distractor types was a within-subject variable.

TABLE I

Response probability for detail and angle probes at each combination of presentation and blank time—Experiment I

		Angle probe Presentation times (ms)				Detail probe Presentation times (ms)			
		250	500	1,000	Mean	250	500	1,000	Mean
Blank	2	0·660	0·710	0·790	0·720	0·620	0·690	0·870	0·730
times	4	0·680	0·720	0·810	0·740	0·730	0·860	0·850	0·810
(ms)	6	0·740	0·740	0·810	0·760	0·600	0·770	0·850	0·740
	Mean	0·690	0·720	0·800	0·740	0·650	0·760	0·860	0·760

There were no significant effects involving blank time, although the interaction between blank time and distractor type approached significance: $F\ (2,54) = 2{\cdot}70$, $P < 0{\cdot}10$. Figure 1 (left panel) shows response probability of exposure time for each distractor type, collapsed over blank times. Recognition performance increased with increases in presentation time, $F\ (2,54) = 15{\cdot}25$, $P < 0{\cdot}05$. While overall performance was slightly better with detail relative to angle distractors, this difference only approached significance, $F\ (2,54) = 3{\cdot}79$, $P < 0{\cdot}10$. Of more importance is the significant interaction between distractor type and presentation time, $F\ (2,54) = 4{\cdot}39$, $P = 0{\cdot}05$. The form of this interaction suggests that for the first 250 ms of viewing a picture, the holistic information assumed to be necessary for the angle discrimination is acquired at a faster rate than is the specific detail information necessary for making the detail discrimination, whereas the reverse is true at longer exposure times. Tests of simple effects indicated that performance was better with the detail relative to the angle

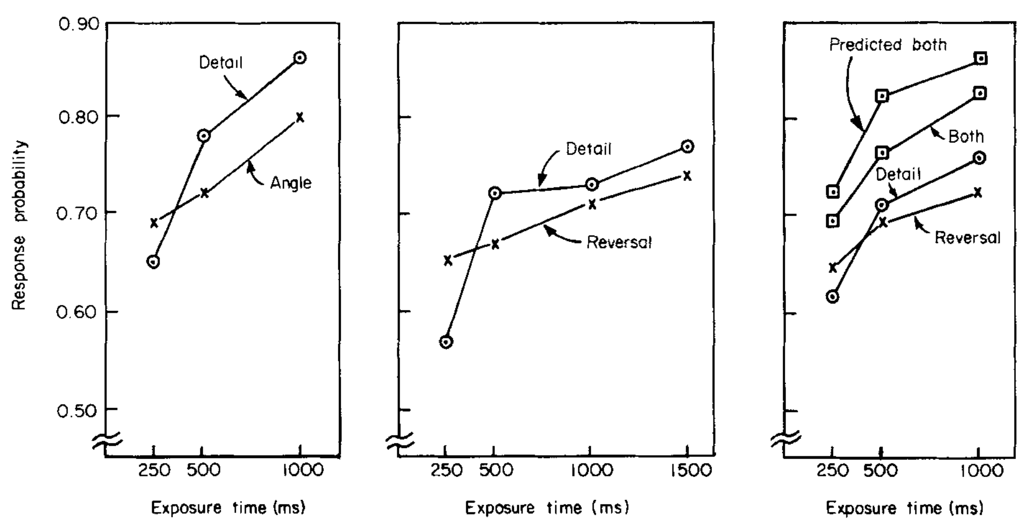

FIGURE 1. Recognition memory performance (response probability) for the three experiments. Panels A, B and C correspond to Experiments I, II and III respectively.

distractors at exposure times of 500 and 1000 ms, $t(54) = 2{\cdot}06$, $P < 0{\cdot}05$ and $t(54) = 2{\cdot}59$, $P < 0{\cdot}05$ respectively. However, the 250 millisecond superiority of the angle distractors was not statistically significant, $t(54) = 1{\cdot}28$, $P > 0{\cdot}05$.

Discussion

The results provide support for the proposition that performance based on specific feature information increases faster as a function of original exposure time than does performance based on the holistic information assumed to be necessary for angle discrimination. This conclusion must be tempered, however, by the lack of a reliable difference between the two distractor type conditions at 250 ms. That is, although the distractor type by exposure time interaction was significant, we cannot be sure that a crossover interaction exists in terms of population means. This, in turn, prevents us from being able to unequivocally reject the null hypothesis for no interaction for all monotone transformations of response probability (cf. Loftus, 1978).

Despite this caveat, the results are consistent with the notion that holistic information as we have defined it is extracted rather quickly from the picture, and the fact that performance based on detail information improves quite dramatically following the first 250 ms of exposure time, is consistent with the view that exposure time following the first 250 ms is used for seeking out specific features. The results do indicate, however, that occasionally a specific feature is encoded during the initial 250 ms of picture viewing; furthermore, some holistic information continues to be encoded as viewing time continues.

The present experiment failed to find an effect of blank time. As noted above, several past studies found increased recognition performance when blank time was increased. However, Shaffer and Shiffrin (1972) failed to find any effect of blank time. Tversky and Sherman (1975) and Weaver (1974) both suggested that one possible reason for the discrepant results was that while blank time was a blocked variable in their studies, it was randomized by Shaffer and Shiffrin; it is possible that subjects could develop effective rehearsal strategies when blank time remained constant within a block of trials. In the present study, blank times were blocked, yet there was no effect of blank time. This null result suggests that the blocking at blank times may not be critical in terms of the effect of blank time on recognition memory. However, blank time was a between-subjects variable in the present study, and the power was not great, so this notion must be viewed with some caution.

Experiment II

Experiment II was carried out for several reasons. First, blank time and exposure time were between-subjects variables in Experiment I, and thus exposure time and blank time were both confounded with the total duration of the study sessions. In Experiment II, blank time was eliminated as a variable, and exposure time was made a within-subjects variable. Second, a new, expanded stimulus set was created for Experiment II to attempt to increase the generality of the results. Third, a noise mask was used in Experiment II so as to better control the amount of processing time for each slide. Finally, as noted previously, the operational definition of "holistic information" was changed in Experiment II. Presence of such information was tested by pairing a target picture with a mirror-image (reversal) distractor.

Method

Subjects

Ninety-six undergraduates from the University of Washington participated in Experiment 2 for course credit. None had participated in Experiment I.

Stimuli

Stimuli were 80 color slide sets of naturalistic scenes. A slide set consisted of four slides that were identical except that two members of the set contained a particular detail, and for the other two, another detail was substituted. Placing one member of a set backwards in the slide tray allowed simultaneous presentation of a picture and its mirror image.

The noise mask that followed each target picture consisted of a random jumble of black and grey lines on a blank background.

Apparatus

At study, stimuli were presented via a Kodak random-access slide projector equipped with a Gerbrands tachistoscopic shutter. A second carousel projector, equipped with an identical shutter, was used to present a masking slide. At test, the two test stimuli were presented via two identical random-access projectors.

Design and procedure

Each slide at study was shown for one of four exposure times: 250, 500, 1000, or 1500 ms. Over subjects, each slide was paired equally often with its detail-change mate and its reversal mate. Additionally, each slide appeared equally often in each exposure-time condition, equally often as target and distractor, and equally often on top and bottom at test. These counterbalancing measures required a total of 32 groups; and three subjects participated in each group. The test presentation order was random with respect to study presentation order.

Detail/reversal and study exposure time were both within-subjects variables. Order of exposure times at study was random with the constraint that equal numbers of observations fall into the eight cells defined by detail/reversal x four exposure times.

The instructions for the study procedure were identical to those of Experiment I. Following questions, 16 practice slides were shown, four at each of the four exposure times. The 80 study trials were then presented. Each trial consisted of a "ready" signal from the experimenter, presentation of the target slide, presentation of a half-second random-noise mask, and a seven-second intertrial interval. The nature of the mask was such that when the mask and a target slide were superimposed, no information could be extracted from the target. At test, the target and distractor appeared one above the other. A target was equally likely to appear on the top or the bottom, and subjects were so instructed. Subjects circled "Top" or "Bottom" on their response sheets to signify their responses.

Results

The major results are presented in the middle panel of Figure I. Again, response probability is shown as a function of exposure time, with separate curves for the detail and reversal conditions. Again, the cross over interaction is seen to occur. The data were analyzed via 2 orthogonal planned comparisons that derived from the Experiment I data. The first comparison revealed that reversal performance is superior to detail performance at 250 ms, $F(1,95) = 9{\cdot}78$, $P < 0{\cdot}05$. The second comparison showed detail performance to exceed reversal performance, on the average, for times greater than 250 ms, $F(1,95) = 3{\cdot}99$, $P < 0{\cdot}05$.

General discussion: Experiments I and II

A similar pattern of results emerged in Experiments I and II. Following 250 ms original viewing—enough time for only a single eye fixation—performance based on the hypothesized holistic information was superior to performance based on specific feature information. At longer exposure times, which allow multiple fixations, the reverse was true.

These crossover interactions—indicating that performance in the detail tests is qualitatively different from performance in the holistic tests—supports the contention that performance in these two types of tests is based on qualitatively different types of information. Based on the form of these interactions, we would like to offer the following account of the relative time courses by which the two hypothesized types of information are extracted from pictures. The first eye fixation falls on a relatively random place in the picture—that is, in the center of the picture where the pre-exposure fixation point had been. Hence, there is little likelihood that the gaze would fall on any interesting specific feature during this first fixation, and the probability of encoding a specific feature would be small. However, as indicated by the results of Loftus and Mackworth (1978), subsequent fixations may well have the purpose of seeking out and encoding specific, high-information features.

The first fixation could, however, be useful for extracting the sort of wide-angle, global, holistic information necessary for making the angle and reversal discriminations. It may also be true that holistic information is acquired on subsequent fixations as well; however, given the hypothesized nature of holistic information, it seems likely that much the same holistic information would be re-acquired on each fixation.

To be somewhat more formal about these notions, we proceed as follows. Our goal is to compare the time course of extracting specific-feature versus holistic information. Unfortunately, there exists no obvious, direct metric that is characteristic of both kinds of information. So to compare them, we must fall back on the common metric of eventual recognition performance. Specifically, we assume that during the ith fixation on a picture, specific feature information that will eventually allow correct discrimination with a detail distractor is acquired with the probability Δ_i. Likewise, with probability γ_i, holistic information that will eventually permit correct discrimination with an angle or a reversal distractor is acquired. Following some number, N, of fixations, the probabilities of correctly responding to detail and angle distractors are functions, D and G of the Δs and γs, respectively, i.e.,

Detail distractors: $p(c_N) = D(\Delta_1, \Delta_2, \ldots, \Delta_N)$

Angle/reversal distractors: $p(C_N) = G(\gamma_1, \gamma_2, \ldots, \gamma_N)$

Note that $D(\Delta_1) = \Delta_1$ and $G(\gamma_1) = \gamma_1$; i.e., following a single fixation, the probabilities of correctly responding are, by definition, equal to Δ_1 and γ_1 for the two types of test trials.

We know from the data (Figure 1) that $\Delta_1 < \gamma_1$. However, we also know from the data that

$$D(\Delta_1, \Delta_2, \ldots, \Delta_N) > G(\gamma_1, \gamma_2, \ldots, \gamma_N)$$

for $N > 1$. There are two possible reasons for this state of affairs. First, the Δs may decrease relative to the γs as viewing of the picture progresses. Second, the functions D and G may differ. Previous research (Loftus and Bell, 1975; Loftus and Kallman, 1979) has provided evidence that the D function may simply combine the Δs independently, i.e.,

$$1 - D(\Delta_1, \Delta_2, \ldots, \Delta_N) = (1 - \Delta_1)(1 - \Delta_2) \ldots (1 - \Delta_N).$$

In contrast, the function G may combine the γs in some less-than-independent manner. Such a notion is simply a restatement of the hypothesis stated earlier that "much the same holistic information is re-acquired on each fixation".

The present data do not allow us to distinguish between these two possibilities. But it seems that either possibility is in keeping with the general idea that holistic information is acquired primarily on the first fixation, whereas specific feature information is acquired primarily on subsequent fixations.

Experiment III

The main purpose of Experiment III was to investigate the degree to which the hypothesized specific feature and holistic information enter independently into a recognition decision. The stimulus set used in Experiment III was identical to that used in Experiment II. The major innovation was the introduction of a third target/distractor relationship condition in which target and distractor differed in terms of both a specific detail and a reversal. With such a design, it is possible to predict performance in this "both" condition from performance in the "detail" and "reversal" conditions under the assumption of independence.

Method

Subjects

Subjects were 108 University of Washington undergraduates who participated for course credit. None had been in Experiment I or II. They were run as 36 groups of 3.

Stimuli

The set of stimuli was the same used in Experiment II, except that only 72 of the 80 slide sets were used.

Apparatus

The apparatus was the same as that used in Experiment II.

Design

Three study exposure times—250, 500 and 1,000 ms were used. These three exposure time conditions were factorially combined with three target/distractor relationships. As in Experiment II, the first two were specific detail and reversal relationships. In the third or "both" condition, the distractor was both a reversal of the target and a specific detail was changed. Both exposure time and target/distractor relationship were within-subjects variables. Each slide appeared equally often in the nine conditions, equally often as target and distractor, and equally often on top and bottom at test, thereby necessitating 36 groups of subjects.

Procedure

The procedure was identical to that of Experiment II, with the exception that the three possible target/distractor relationships were explained to subjects at the time of the test.

Results

Response probability for the nine conditions is shown in the right panel of Figure 1. Several aspects of these results are noteworthy. First, considering the detail and reversal conditions only, the exposure time by distractor type interaction seen in the first two experiments is replicated in terms of the sample means. The magnitude of the effect is not as great, however. No obvious reason for the weakened effect presents itself, but it should be noted that there was not as much data per condition as in Experiment II, and hence not as much statistical power for any given comparison. The second noteworthy effect is that performance in the "both" condition is substantially better than performance in either the detail or the reversal condition for all three exposure times, $t(107) = 5{\cdot}88$ $P < 0{\cdot}05$. Thus, the information underlying detail and reversal responses are combining at least partly independently in the "both" condition.

To be more precise about the independence issue, it is necessary to specify a model of response processes that will take guessing into account. The most straightforward model would assume that a correct response in the "both" condition is made if appropriate specific detail information has been acquired, or if appropriate holistic information has been acquired, or with a guessing probability 0·5. Referring to b as the predicted probability for the "both" condition, the independence model yields:

$$(1 - b) = (1 - r)(1 - d)\ .5$$

where r and d are probabilities corresponding to the reversal and detail conditions that are corrected for guessing by the transformation $x' = 2x - 1$. Equation 1 reduces to

$$b = (1 + r + d - rd)\ .5$$

The top line of Figure 1, right panel shows the three predicted probabilities. In each case, they overestimate the observed probabilities by about four percentage points. Collapsing over the three exposure times, this difference was significant over subjects, $t(197) = 3{\cdot}45$, $P < 0.05$. Thus we can conclude that the two types of information are not combining completely independently—rather, there is some shared information contributing to performance in the reversal and the detail conditions.

Given the way that we operationalized the two types of information, this finding is not surprising—indeed, it would have been more surprising had the data indicated complete independence. To see why this is so, suppose that a subject encodes the presence of an object in a picture. This information would be sufficient to perform correctly on a subsequent recognition test in which that object was the critical one. However, it is reasonable to suppose that while encoding of the presence of the object, some information about the object's orientation is encoded as well; and this information could be used in making a correct reversal discrimination.

Conclusions

The motivation for the present research stemmed from the apparent need to postulate specific feature and holistic information as potential bases for picture recognition responses. The primary purpose of the three experiments was to investigate some of the properties of these two types of hypothesized information. But as is so often the case in psychological inquiry, we are faced with a conceptual catch-22. To investigate the properties of the hypothesized information, we must operationalize it in some way; however, without knowing much about the properties, it is not terribly clear how the operationalization should be done. Hence a bootstrapping strategy is required in which operationalization is arrived at partly by logic and partly by intuition. The properties of interest are then examined, and some decision is made as to whether these observed properties make sense.

As noted earlier, the notion of "specific feature information" is one that has enjoyed experimental attention from investigators in a variety of areas (Friedman, 1979; Loftus and Bell, 1975; Loftus and Kallman, 1979; Schank and Abelson, 1975). In contrast, "holistic information" is still a vague notion, whose properties have been only hinted at in past research. It is encouraging, therefore, that operationalization of holistic information in two different yet intuitively reasonable ways both yielded the same, quite sensible pattern of results in Experiments 1 and 2. It would have been even more encouraging if complete independence had been found in Experiment 3, as this would have provided both additional support for the theoretical distinction between these two types of information, as well as support for the mode of operationalizing holistic information. The results we obtained indicate either that these two types of information are not completely independent, or that our operationalization of them could bear improvement or both.

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